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THE DEVELOPMENT OF GELASIMUS AFTER HATCHING

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TWELVE PLATES (EIGHTY-EIGHT FIGURES)

During the summers of 1915 and 1916 at the U. S. Fisheries Biological Station at Beaufort, North Carolina, while engaged in an endeavor to rear crustacean larvae under artificial conditions, I had an opportunity to study the habits and developmental stages of Gelasimus. While this study was only incidental to the experiments in hand, I found the material so abundant and other conditions so favorable that I have been enabled to review the development in considerable detail. During the progress of the study I have been aided greatly by the criticism and guidance of Dr. H. V. Wilson and Mr. W. P. Hay. The work done at Beaufort has been made a pleasure by the generous cooperation unfailingly extended by Mr. S. F. Hildebrand, director of the laboratory.

OCCURRENCE OF THE ADULTS

Of the many decapods at Beaufort, the three species of Gelasimus are perhaps the most numerous. Gelasimus pugilator, the common gray sand-fiddler or fiddler crab, is present almost everywhere, but is most abundant on the islands and shores where a sandy beach is exposed at low tide. Conditions are especially favorable if the beaches have a fringe of sedges which are in the water at high tide. The crabs find a ready refuge in these when frightened.

Gelasimus pugnax is not so abundant as G. pugilator, but is rather common. It is most often found in marshes, especially where there is a considerable estuary formed at high tide, but where the soft boggy marsh is exposed when the tide is out. One such estuary leads north from Taylor's creek, a few hundred yards west from Lenoxville Point. This species is also abundant on the banks of the Beaufort end of the Inlet Canal from Pamlico to Beaufort.

The third species, Gelasimus minax, is not common. It seems to prefer higher ground bordering a marsh, and frequently occurs at some distance from salt water. It occurs along the banks of the Inlet Canal from Pamlico to Beaufort, and especially in one of the large estuaries on the Shackelford Banks east of the Mullet Pond.

METHODS OF STUDY

In studying the larval history of these forms, the first zoeae were hatched in the laboratory. The ovigerous females of G. pugnax and G. minax were secured readily by digging them from their burrows in the marshes. Egg-bearing females of G. pugilator at first were very hard to find. I have dug the crabs from their burrows for hours and searched the hundreds at the water's edge at ebb tide without finding a single ovigerous female. Quite by accident I discovered a method of securing all the eggs of this species to be desired. Landing on Horse Island just at dusk one evening, I noticed that a number of the fiddlers hurrying to their burrows were egg-bearing females. Investigation showed that a large percentage of the females carried eggs. Thereafter I had no difficulty in securing all the eggs I wished by going to some favorable spot at dusk during an ebb tide. The crabs were taken to the laboratory and kept in crystallization dishes partially filled with water, until the eggs hatched. Generally the eggs hatched within a few days. The approximate age of the embryos can be determined at a glance. When the eggs are newly laid they are a deep purple—almost black. As the embryo develops it becomes lighter and distinctly purple. It continues to lose its color, becoming a dirty gray when it is nearly ready to hatch. The eggs of all three species hatch soon after 7 P.M., that is, at about dusk. This fact probably explains the presence of the females at the water's edge at that time.

Rearing the larvae. During the summers of 1915 and 1916 I made many unsuccessful attempts to rear the larvae secured by hatching the eggs while they were still on the female. I carried one solitary specimen through three molts, several through two molts, and many through one molt, but the great majority of the zoeae died before their first molt. The only method by which I succeeded in carrying any beyond the first molt was as follows: Small floats, 6 inches by 8 inches by 2.5 inches, with sides of fine bolting cloth, were made. The zoeae were placed in these and these bolting-cloth floats then placed in crab floats for protection from the rippling of the surface water. The difficulty with this method was that debris rapidly collected on the float and clogged its meshes. The bolting cloth rotted quickly and it was difficult to recover the zoeae.

Larvae from the tow. The fifth zoea and the megalops and crab stages were not reared from the egg. The method of tracing the development through these stages was to collect specimens of some known stage from the tow and keep them in the laboratory until the next molt. The zoeal stages could rarely be kept alive through more than one molt. On the other hand, the megalops and crab stages could be kept alive indefinitely if they were fed and protected from the cannibalistic tendencies of their fellows.

The stages for study were obtained as follows. The first, second, and third zoeal stages were abundant in the surface tow from July 1st to September 15th. The tow might be taken anywhere in the harbor or outside. The stages could be separated with some difficulty and placed in glass bowls. The next molt generally occurred in a few days.

The fourth and fifth zoeal stages seldom appeared in the surface tow. These stages, however, could be obtained readily from the bottom tow. The method of towing on the bottom was as follows: A bolting-cloth sac was made to fit inside a small heavy, bottom dredge. This was then dragged carefully along with just enough rope to let it touch the bottom. Care must be exercised to keep it from digging. The only successful tows of this kind were taken over a sandy bottom. The best place was found to be along the southwest edge of Bird Island Shoal.

Megalops and crab stages. The specimens of megalops were taken most abundantly in surface tow from the ocean just outside the inlet. They were also taken in numbers from crevices in rotting boards exposed at low tide, under oyster shells and stones, or from the bark on pilings. The crab stages do not appear in the tow. They may be picked from the old boards, with the megalops stages, or obtained during ebb tide on a sandy beach (where they are very hard to see) or in the debris in the marshes. After the crab measures about 2 mm. across the carapace, it digs its own burrow and may then be collected by digging. All of the crab stages are found mingled with the adults.

HISTORY OF THE DEVELOPMENT

From the foregoing facts the following history of the development may be deduced with reasonable assurance. The egg-laden females remain hidden in their burrows during the day, probably because the egg mass retards their movements to such an extent as to endanger their existence. At dusk, when the eggs are ready for hatching, the females approach the water's edge and the eggs are hatched in the water. The larval skin with which the embryo is covered is shed in hatching.

The young zoea wobbles off on the surface of the water, being carried along largely by the tide. Its own efforts, however, serve to keep it at the surface, all the zoeal forms being positively phototropic. After about four days the first molt occurs. The second zoea behaves like the first—keeps itself near the surface of the water by the rapid beating of the maxillipeds and is swept along by the tides. After four or five days a second molt occurs. The third zoea is the form most rarely found in the tow. This indicates the possibility that it swims at an intermediate depth, the maxillipeds not being strong enough to sustain at the surface the increased weight of the body.

After the molt to the fourth zoeal form, the zoea sinks. It does not lie or crawl on the bottom, but is swept along by the current and at short intervals drives itself upward by the rapid beating of the maxillipeds. As soon as the maxillipeds cease beating it falls slowly to the bottom again on account of its weight. After about a week the next molt occurs. The fifth zoea lives near the bottom like the fourth. It is still more disproportionately heavy and correspondingly clumsy. During the last day or so of this stage the animal is almost entirely at the mercy of the tide. The next molt occurs at the expiration of a week or ten days.

When the zoea molts to the megalops stage, its mode of life suddenly changes. The animal is now provided with powerful swimming organs, the pleopods, so situated as to be most efficient. Its chelae serve as an excellent means of securing its prey, which now consists, partly at least, of smaller crustaceans. Its organs of equilibration are suddenly well developed and its other sense organs are more nearly perfect. The animal rapidly ascends to the surface and darts swiftly about. The megalops stage probably lasts a long time, and there is only one such stage. Megalopa were kept in the laboratory as long as three weeks before molting to the crab stage. All of those that molted became crabs at the first molt. After swimming about at the surface for three or four weeks, the megalops seeks some protected place, such as the crevices in a rotting board near the shore, and there undergoes the molt to the first crab stage.

The young crab clings closely to its refuge or crawls about at the water's edge, especially among the exposed roots of sedges. It is very clumsy and very weak. At the end of three days it molts to the second crab stage. After four or five days a second molt occurs. After this molt the little crab runs about quite freely and may dig its first burrow. It now measures about 2 mm. across its carapace at its broadest point. Its mode of life from now on is like that of the adult.

IDENTIFICATION OF THE ZOEAE

The zoeal forms of Gelasimus may be identified readily. They have prominent anterior and dorsal spines, but have no lateral spines on the carapace. This distinguishes them at once from all the other common zoeae of the Beaufort region, except those of the two species of Sesarma. From these the zoeae of Gelasimus may be distinguished in two ways: the length of the antenna does not equal that of the anterior spine in the case of Gelasimus, but does in Sesarma; the first maxillipeds of Sesarma have pigment spots at the proximal ends of the protopodites, while in Gelasimus the first maxillipeds have pigment spots at the distal ends of the protopodites.

The pigmentation of all the zoeal stages of Gelasimus is remarkably constant and serves as a ready means of establishing the identity of the form. The pigment spots are jet-black when contracted. In the expanded condition they vary in color, being black or olive or red-brown or orange or combinations of these colors. The distribution of the spots is as follows: on the carapace, a spot posterior to the base of the dorsal spine, a spot on each lateral flange of the carapace near its posterior angle, a median spot between the eyes, a large spot on the front of the base of the anterior spine, a spot between the bases of the first and second maxillae; on the appendages, a spot on the labrum, one on each mandible, and one on the distal border of the protopodite of each of the first maxillipeds; on the abdomen, a pair of dorso-lateral spots between the first and second segments, a pair of ventral spots on the second and third segments, and lateral spots on each side of the posterior borders of the fourth and fifth segments.

DISTINGUISHING CHARACTERISTICS OF THE ZOEAL STAGES

The first and second zoeal stages of the three species were obtained with certainty by hatching and rearing them in the laboratory. The distinctions between equivalent stages of the three species, however, all proved to be relative differences of such slight degree that I was never sure that I could separate certainly the specimens obtained from the tow. Some specimens had the characteristic broad-based, evenly tapering frontal spine of G. pugilator and others the slender constricted spine of G. pugnax, but many of them seemed intermediate, and I gave up the attempt to distinguish the species. The different developmental stages of the zoeae were easily distinguishable from each other, however, as is indicated in the descriptions below.

First zoeal stage of G. pugilator (figs. 1 and 2). These zoeae are relatively small (length from head between the eyes to tip of telson, 1 mm.). They swim by means of the first and second maxillipeds, and, so far as was observed, swim in only one direction, upward and slightly forward. When at rest the maxillipeds are habitually carried in the position shown in figure 1. In swimming, these are raised to the sides of the carapace and driven downward. When not swimming, the larva is nearly always actively writhing about, chiefly by lashing the abdomen. The first and second maxillae beat regularly and rapidly in such a way as to drive a current toward the mouth opening.

The carapace is slightly flattened from side to side. It bears the usual anterior and dorsal spines, but shows no traces of lateral spines. The anterior spine rises from the anterior margin of the carapace between the eyes and passes ventrally almost at right angles to the long axis of the body. It is about 0.2 mm. long, straight, smooth, and evenly tapering from a slightly swollen base. The dorsal spine arises in the mid-dorsal line posterior to the eyes and just above the heart. It is shorter than the anterior spine and curved posteriorly. There are constantly present a pair of setae which arise on each side of the carapace, anterior and lateral to the base of the dorsal spine. The lateral ventral borders of the carapace show the usual anterior and posterior lobes.

The eyes are sessile and immovable. The facets are clearly indicated, but are not perfectly marked on the surface. The antennule (fig. 20) is 0.07 mm. long and conical. From its tip arise two or three long olfactory hairs and one or two short, sharp-pointed setae. The antenna (fig. 28) is 0.11 mm. long and bisegmented. The proximal part of the basal segment is thick and cylindrical. At its distal end its inner half is produced into a stout serrated spine about twice as long as the proximal portion. The outer half of the tip of the basal portion bears the distal segment, which is small and cylindrical. From its tip arise two setae, one long, which seems to be a continuation of the segment, and a short outer one.

The mandible is short, stout, and unsegmented. Its edge has the usual teeth for tearing and grinding. The first maxilla (fig. 45) is bisegmented. The basal segment is bilobed and thickly lamelliform. The medial lobe bears one movable smooth spine on its median border, and, at its tip, three macerating spines. The lateral lobe bears similar spines arranged in two series. From the distal border of the lobe arise two or three strong spines, and from its inner face, near the border, arise three weaker spines. The distal segment is cylindrical and bears four tactile hairs at its tip.

The second maxilla (figure 54) is a lamellar appendage, its median border produced into four lobes and a hairy process extending laterally. The three median lobes represent the basal segment or segments. Of these, the most median bears two series of smooth spines. The middle and lateral lobes of the basal segment are each armed with three macerating spines at their tip and one on their inner surface near the tip. The fourth lobe represents the distal segment. It bears three tactile hairs at its tip. The outer plate represents the epipodite. It consists of a proximal lamelliform portion which bears four finely plumose hairs along its lateral border, and is produced posteriorly into a process which tapers to a blunt end. The process is covered with fine hairs over most of its suface.

The first maxilliped (fig. 62) is the best developed of the appendages at this time. It is 0.25 mm. long without its terminal hairs. It is composed of a basal portion, an endopodite, and exopodite. The basal portion is unsegmented, compressed, and of approximately uniform circumference. The endopodite, slender and slightly longer than the basal portion, is composed of five segments. The terminal segment bears three tactile hairs at its tip and a single plumose seta from its median superior surface. The exopodite is unsegmented, cylindrical, and about equal in length to the endopodite. It bears four long plumose hairs which are jointed near their middle. The length of the hairs is from 0.16 to 0.20 mm.

The second maxilliped (fig. 62) is like the first in all respects except its endopodite. This is much shorter and is trisegmented.

The two basal segments are very short, the terminal segment is like the terminal segment of the endopodite of the first maxilliped.

The abdomen is composed of five movable segments. Each of the first four is cylindrical and of approximately the same diameter. They increase slightly in length from the first to the fourth. The second, third, and fourth segments are produced backward and laterally into an angular process which slightly overlaps the next succeeding segment. The posterior border of each of these segments bears a median seta dorsally. The second segment bears a short blunt lateral spine which curves forward. It is so placed that its curvature serves as a groove into which the posterior border of the carapace fits. The third segment also bears a spine which curves backward on each side and is less conspicuous. The terminal segment represents the sixth abdominal segment fused with the telson. It is crescent-shaped with the horns elongated. The anus lies on the ventral surface of this segment. It is surrounded by very tumid, movable lips. which may form a protuberance as in figure 1. From the median surface of each horn near its base, three setae arise which are plumose with short stout hairs. The length of the segment with its horns is 0.22 mm.

First zoeal stage of G. pugnax (figs. 3 and 4). The first zoea of G. pugnax differs from that of G. pugilator only in size. It is smaller in all dimensions. The anterior and dorsal spines are shorter and slenderer. Otherwise there is the most absolute identity in pigmentation and conformation of the appendages—even to the number and kind of hairs found on each.

First zoeal stage of G. minax (figs. 5 and 6). The first zoea of G. minax is distinguishable from that of G. pugnax with the greatest difficulty. It is slightly smaller, but shows the same slender spines of the carapace.

The first zoeal stage of Gelasimus (figs. 1 to 6) is most readily distinguished by the four plumose hairs of the exopodites of the maxillipeds. The caudal portion of the scaphognathite is a single elongated conical process thickly beset with fine hairs.

The second zoea (figs. 7 and 8) has increased in length to 1.175 mm. The eyes are on stalks and are slightly movable. The lateral hairs on the scaphognathite are now five and the posterior conical portion is tripartite distally (fig. 56). The exopodites of the first and second maxillipeds become bisegmented and the number of hairs at their tips is increased to six.

The third zoea (figs. 9 and 19) has increased in length to 1.5 mm. The eyes are freely movable. A broad, low tubercle appears between the spine of the basal segment of the antenna and the base of the distal segment (fig. 30). This is the anlage of the flagellum of the permanent antenna. The distal portion of the first maxilla (fig. 48) has two segments and has become separated from the basal portion by a joint. In the second maxilla (fig. 57) the scaphognathite now bears six hairs along the lateral border of its anterior portion. The exopodites of the first and second maxillipeds bear eight hairs. The third maxillipeds are clearly distinguishable for the first time as minute buds just behind and somewhat median to the second pair. The buds of four pairs of periopods are distinguishable and those of the cheliped are somewhat larger and show an identation at their tips indicating the position of the chela. Blunt protuberances from the ventral surfaces of the second to sixth abdominal segments are the beginnings of the pleopods. On the telson (fig. 84) are two minute spines medial to those earlier present. There is a deep groove between the sixth abdominal segment and the telson, but no joint has yet developed.

The fourth zoea (fig. 11) has increased in length to 2 mm. The antennule has increased in size somewhat and a lateral hair is present near its tip (fig. 24). The tubercle of the antenna is greatly enlarged and the former distal segment now appears as a lateral appendage (fig. 32). The second maxilla shows several changes (fig. 58). The palp is separated from the basal portion by a joint and the median lobes are more pronounced. The scaphognathite appears as a single plate and bears eighteen hairs along its lateral border. The first and second maxillipeds have nine or ten hairs at the tips of their exopodites. The bud of the third maxilliped is notched at its tip, indicating a division into two rami. The buds of all the periopods appear, and those of the chelipeds are clearly bifurcated. The buds of the pleopods have become more prominent. The border of the carapace bears a series of straining hairs which serve to keep foreign particles from getting under it.

The fifth zoea (figs. 12 and 13) has increased in size to a length of 2.25 mm. The antennule (fig. 25) shows the following changes: a rather deep constriction divides the distal portion from the slightly enlarged basal portion; on the distal portion the number of hairs of the second series is increased from the single one to three. When this stage is nearing its molting time, the distal portion shows indistinctly two or three constrictions where the joints of the next stage will appear. In the antenna (fig. 33) the flagellum is bisegmented and is marked off by a joint. As the time for the next molt approaches, the flagellum shows indications of about twelve constrictions which mark out the joints of the next stage. The first maxilla shows a few minor, but interesting changes (fig. 50). There is developed on its lateral border a rounded low prominence which bears a single sparsely plumose stout hair similar to those found on the coxopodites of the maxillipeds at the base of the epipodite. Between the palp and the epipodital prominence is a peculiar, densely plumose hair similar in structure to the hair on the distal segments of the endopodites of the first and second zoeal maxillipeds and to the so-called 'auditory hair' of Mysis. The exopodites of the first and second maxillipeds bear ten hairs (figs. 66 and 67). The endopodite of the second maxilliped has grown considerably larger. The third maxillipeds and the periopods are finger-shaped appendages, and two or three small buds dorsal to their bases are the early gills. The pleopods are also finger-shaped and show indications of division into protopodite, exopodite, and endopodite, although the endopodite is exceedingly minute. The telson bears four pairs of plumose spines. During the last day or two of this stage a number of changes are noticeable in preparation for the next molt. The soft part is withdrawn from the dorsal spine, until it is entirely empty, and from the anterior spine until it fills the basal fourth only. The exopodites of the maxillipeds are shrunken away from their coverings, thus accounting for the sluggishness of the larva at this time. All the joints of the periopods are differentiated.

Description of the Megalops (figs. 14 and 15). When the fifth zoea molts to the form of the megalops, a profound change occurs in many of the parts. The contours of the cephalothorax and the abdomen are both changed. Throughout the zoeal stages the cephalothorax is flattened from side to side. In the megalops it is flattened dorso-ventrally. The abdomen is cylindrical in the zoea and now becomes flattened dorso-ventrally also. The changes in many of the appendages are still more striking. The animal suddenly becomes well equipped for an active predatory existence. The sensory structures of the antennule and the antenna are practically in the adult condition. The chelae are efficient structures for securing the prey and the maxillipeds are transformed into masticatory organs. The pleopods are now developed into powerful swimming organs and the animal darts swiftly about.

The antennule (fig. 26) is now composed of a large basal portion and a terminal process of four segments. The basal segment bears the statocyst which can be distinguished through its walls. The ultimate and penultimate segments bear from five to seven olfactory hairs each. The antennule has now reached what is practically the adult condition. The antenna has undergone a striking change (fig. 34). The zoeal lateral spine and lateral segment are absent. The flagellum is composed of eight small cylindrical segments and is borne at the tip of a basal portion of three larger segments. The antepenultimate segment of the flagellum bears four or five long tactile hairs and the terminal segment two or three.

The mandible (figs. 40 and 41) has reached practically the adult condition, as it now bears a three-jointed palp. The first maxilla (fig. 51) shows few changes. Its basal median lobe bears more spines and is enlarged. The joints of the palp are obscure and its segments somewhat shriveled. The hairs on the lateral border of the basal portion have the same form as the hairs on the epipodites of some of the appendages posterior to it. The second maxilla (fig. 60) has undergone changes similar to those of the first. The palp has lost its hairs and joint and appears as a smooth lobe of the basal portion. The scaphognathite is larger and has more hairs along its border.

The changes in the maxillipeds are profound (figs. 68, 70, and 74). The first and second pairs are transformed from swimming organs and all three pairs become functional as mouth parts. The first and third pairs bear well-developed epipodites, and each of the second pair bears a tiny bud on its lateral surface—the beginning of an epipodite and a gill. In all these appendages the proximal segment of the exopodite is elongated and slender, while the distal segment is small and is carried at right angles to the basal segment. It bears three or four weak, slender, plumose hairs. The endopodite of the first pair is twisted so that the lateral edge of its distal portion becomes median. It bears only a few small hairs. The endopodites of the second and third pairs are composed of four segments, are stout, and bear numerous macerating spines.

The gills of the megalops are four on each side—a pleurobranch between the third maxilliped and the cheliped, two podobranchs on the cheliped, and one podobranch on the second periopod.

The chelipeds are large and functional as pincers. The second, third, and fourth periopods are long and slender with somewhat hooked extremities. They may be used in crawling, but are used chiefly for clinging to some protecting cover. The fifth periopod seems to be useless. It is small and has several long hairs at its tip, and is carried folded over the back of the carapace.

The pleopods (fig. 79) are large, well-developed swimming organs. Each is composed of a basal segment bearing an exopodite and an endopodite. The exopodite is a flattened lobe bearing from seven to fourteen swimming hairs around its border. The endopodite (fig. 81) is small, bears no hairs, but has three shriveled, curled processes at its tip which may represent atrophied hairs.

The first crab stage (fig. 16). When the megalops molts to the first crab stage, the cephalothorax is slightly altered, becoming broader and more depressed. The abdomen shows a great change. It is permanently flexed under the thorax into a groove in which it fits, and its appendages, the pleopods, are shriveled and hidden under it.

The antennules and antennae show only slight changes. The mandible and first maxilla are very slightly altered also, but the second maxilla (fig. 61) is changed both in shape and in the relative size of its parts. The scaphognathite has increased in size; the two basal lobes are larger and are partly constricted from the coxal segment; the palp is relatively smaller and is reduced to an inconspicuous lobe of the lateral basal lobe.

The maxillipeds (figs. 69, 71, and 75) show changes, but none so marked as in the previous molt. In the first, the change is largely an increase in size and apparent strength. The endopodite has changed shape and is now a trisegmented, flattened appendage with the middle segment twisted or folded on itself. All its segments are hairy. The basipodite and coxopodite appear as prominent rounded lobes medially, but fuse into an unjointed mass laterally. Each lobe has a spiny border. The epipodite is larger and bears scattered, slender, barbed hairs. The second maxilliped is not greatly changed. The proximal segment of the endopodite is relatively larger and bears a row of stout spines along its median border. The tubercle of the future gill and epipodite shows a differentiation into minute lobes. The change in the third maxilliped is largely confined to the endopodite, which is relatively larger, due to an increase in size of the proximal two segments. The number of hairs is increased on all segments, but especially on the lateral portions of the protopodite and the proximal half of the epipodite.

The chelae are further developed. Both the carpus and the dactyl end in rounded, spoon-shaped points. Both chelae are identical. The fifth periopods are adapted for walking and clinging. They are small, but have the usual five segments of the periopods.

The most striking change among the appendages occurs in the pleopods. These are no longer the well-formed, powerful swimming organs of the megalops, but are smaller, hairless, and shriveled. They are hidden between the abdomen and the thorax.

The second crab stage (fig. 17). After the next molt the crab has increased in size from 1.35 mm. long and 1.25 mm. broad to

1.5 mm. long and 1.9 mm. broad, thus showing a relative broadening of the carapace. The lateral borders of the carapace are still lobulated and beaded, but not so prominently as before. The only changes of note in the appendages are the assumption of adult form by the antenna (fig. 36) and further reduction of the pleopods. The antenna is now made up of a large basal segment and a flagellum. The proximal two joints of the flagellum are distinct, but the others are reduced to surface constrictions. The pleopods are distinguishable as minute, shriveled appendages on the second, third, fourth, and fifth abdominal segments, but are absent from the sixth. The abdomen has begun to broaden by the development of lateral flanges.

The third crab stage (fig. 18). There is no pronounced change at the next molt except in the pleopods. They may be entirely absent in this stage or may be present on the first to the fifth segments as buds so minute as to be indistinguishable under magnification less than five hundred diameters. Those on the second segment may be larger than the others. The abdomen has become broader.

Beginning of sexual differentiation. After the next molt the young crab attains a width of carapace of 3 mm. This stage shows the beginning of sexual differentiation; in males one chela is slightly larger than the other. Abdominal appendages of a second series make their appearance. These develop into the genital appendages of the adult. In male specimens appendages are present as minute buds on the first and second segments. In the female buds are distinguishable with difficulty on all the the segments from the second to the fifth.

Description of a 4-mm. crab. When the crab reaches a width of 4 mm. across the carapace, the sexual differentiation is pronounced and other important changes have occurred. The carapace now has the adult shape with straight sides. Numerous very brushy hairs have appeared on its anterior surface below the orbits. The abdomen is still further flattened and its segments seem to be more or less completely fused except at their lateral borders. The telson, however, is freely movable, being joined to the rest of the abdomen by a membranous joint. The whole abdomen fits tightly into its groove on the thorax. Its lateral borders are beset with numerous straining hairs. The hairs around the telson are numerous and brushy.

The eyes (fig. 19) have now reached their adult condition. They are bisegmented and the terminal segment bears the compound eye facets over its distal and lateral faces. The eyes are carried erected over the carapace in this stage, but may be lowered into their imperfect orbits for protection.

No changes have occurred in the first five pairs of appendages except slight changes in the relative sizes of some of their parts and a multiplication of the hairs on each.

The first and third maxillipeds show no change of importance. They are more hairy and some of their hairs have developed into so-called 'comb hairs.' On the second maxilliped (fig. 73) the gill and the epidodite are now developed, although both are quite small. The gills present in this stage are as follows: a podobranch on the second maxilliped; two arthrobranchs or pleurobranchs between the third maxilliped and the cheliped; two pleurobranchs at the base of the cheliped, and one pleurobranch at the base of the second period.

In the female the chelipeds are not differentiated, but both remain small with spoon-shaped extremities (fig. 78). In the male, one of the claws is considerably enlarged, is thicker, and is adapted to cutting and pinching (fig. 77). The spoon-shaped chelae are especially adapted for scooping up the fine sand from which the animals get their food.

The abdominal appendages are now modified to form sexual organs. In the male, the appendages of the first and second abdominal appendages only are present. Each consists of two segments. The appendage of the first segment is composed of a rather broad basal portion and a rod-like distal segment. The distal segment is grooved along its median border. The appendage of the second segment is much smaller than that of the first, but has the same enlarged basal segment and rod-like distal segment. The distal segment, however, is cylindrical. In the female, appendages appear on the second to the fifth segments. Each is composed of a basal portion and two rami. Both rami are cylindrical and the endopodite is bisegmented. None of the parts are separated by distinct joints as yet. The appendages of the second segment are the largest, the others becoming progressively smaller from before backward.

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